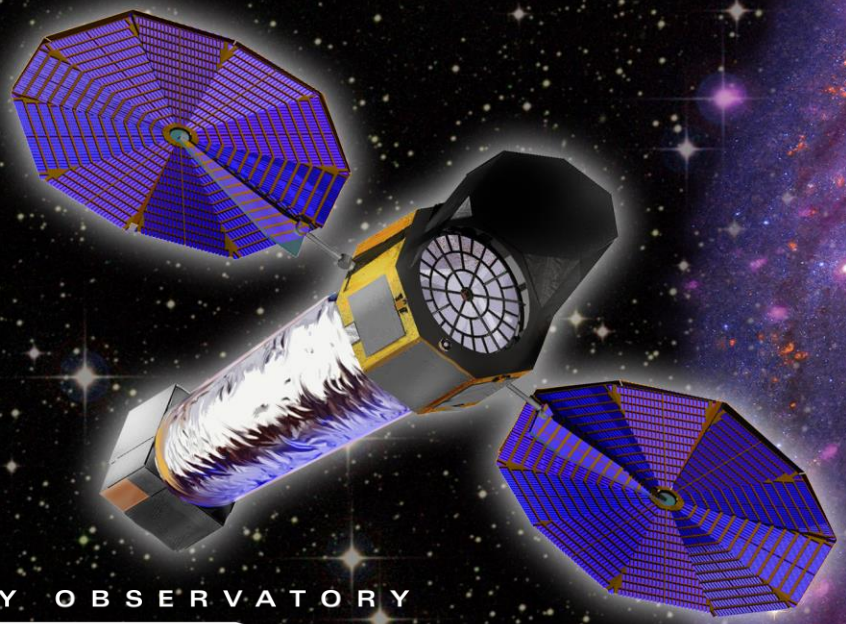
The *Lynx* Mission Concept
2017 Accomplishments and 2018 Goals

Dr. Jessica A. Gaskin (Study Scientist, MSFC)

-Presented On behalf of the *Lynx* Team



X-RAY OBSERVATORY

LYNX

Meet *Lynx*!

One of 4 large missions under study for the 2020 Astrophysics Decadal, Lynx is an X-ray observatory that will directly observe the dawn of supermassive black holes, reveal the invisible drivers of galaxy and structure formation, and trace the energetic side of stellar evolution and stellar ecosystems.

Lynx will provide unprecedented X-ray vision into the "Invisible" Universe with leaps in capability over *Chandra* and *ATHENA*:

- 50–100× gain in sensitivity via high throughput with high angular resolution
- 16× field of view for arcsecond or better imaging
- 10–20× higher spectral resolution for point-like and extended sources

Lynx will contribute to nearly every area of astrophysics and provide synergistic observations with future-generation ground-based and space-based observatories, including gravitational wave detectors.

Decadal Deliverables Updated Schedule

X-RAY OBSERVATORY LYNX

ASTROPHYSICS

Study Deliverables

NASA

M1	**Comments on Study Requirements and Deliverables** – Accept the study requirements/deliverables and submit plan--- or – Provide rationale for modifying requirements/deliverables	**April 29 2016**
O1	***Optional: Initial Technology Gap Assessment*** – *To impact PCOS/COR/ExEP 2016 technology cycle*	**June 30 2016**
O2	***Optional: Update Technology Gap Assessments***	**June 2017**
M4	**Interim Report** – Provide science case and mission concept (use CML 3 as a guide) – Deliver initial technology roadmaps; estimate technology development cost/schedule – CML 4 tailored approach (optional)	**March 2018**
O3	**Update Technology Gap Assessments**	**June 2018**
M6	**Draft Final Report at Concept Maturity Level 4 Audit / Freeze Point Design** – Provide science case and mission concept (use CML4 as a guide) – Support independent cost estimation/validation process – Submit to HQ for CATE	**Jan 2019**
M6'	**CATE report returned by HQ to STDTs for incorporation into M7**	**May 2019**
M7	**Final Report / incorporate CATE report + final changes** – As described in study success criteria chart 15	**June 2019**
M8	**HQ Submits final report to Decadal**	**July 2019**

***Note: Schedule relaxed from original by ~4 months due to decadal committee schedule delay**

New Members!

X-RAY OBSERVATORY LYNX

STDT Members

Zoltan Haiman,
Columbia

Terri Brandt,
PCOS Program Office
Acting Chief Scientist

Andrey Kravtsov,
Chicago

- 22 STDT Members
- 8 Science Working Groups
- Optics Working Group
- Calibration Working Group
- Communications Working Group
- Instrument Working Group
- Ex-officio International members

Over 275 total members!

Ex-Officio

Peter Jonker,
SRON-Appointed

Giovanni Pareschi
INAF-Appointed

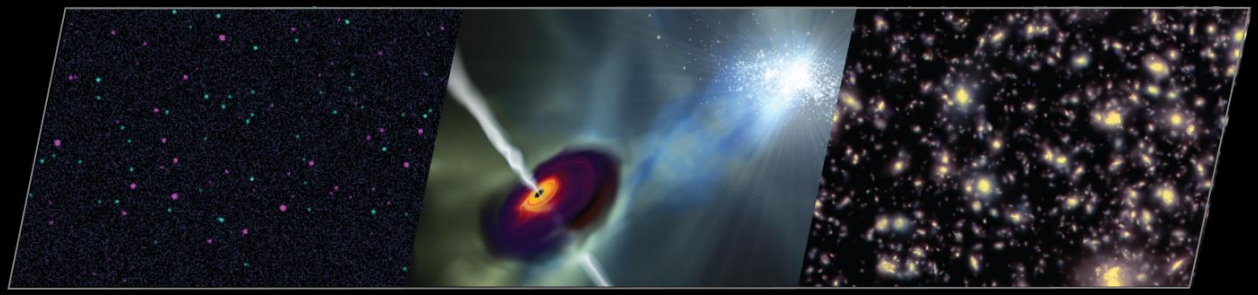
Science of *Lynx*

X-RAY OBSERVATORY LYNX

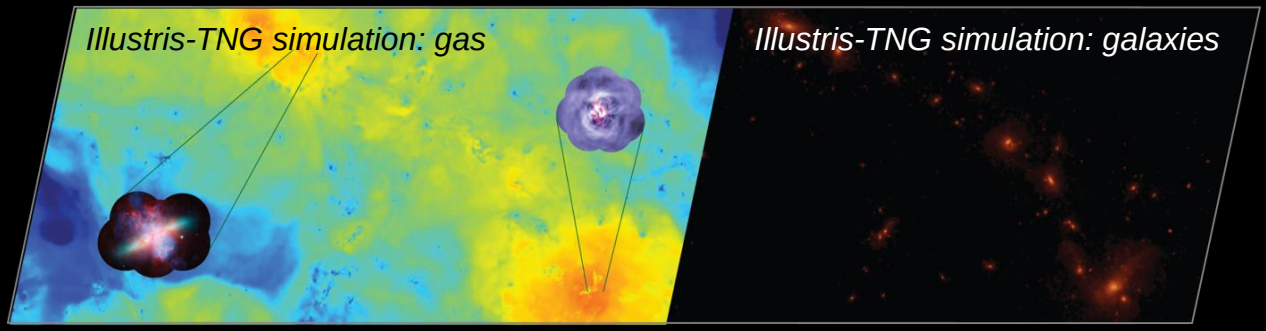
The Dawn of Black Holes

Lynx deep field

JWST deep field



The Invisible Drivers of Galaxy and Structure Formation



The Energetic Side of Stellar Evolution and Stellar Ecosystems

Endpoints of stellar evolution

Stellar birth, coronal physics, feedback

Impact of stellar activity on habitability of planets

AAS *Lynx* Science Talks

- Monday, 9:45AM-10:05AM, Grav. Wave SIG, Lynx and LISA, R. Petre
- Tuesday, 10:00AM-11:30AM, 103.04: Lynx Mission Concept Study, A. Vikhlinin
- Wednesday, 2:00PM-3:30PM, 223.08, Future prospects with the Chandra and XMM source catalogs: Setting the stage for Lynx, R. Hickox
- Thursday, 2:00PM-3:30PM, 332.01: Implications from XMM and Chandra Source Catalogs for Future Studies with Lynx, A. Ptak
- Thursday, 5:30PM-6:00PM, 350.01: Looking for Dust Scattering Light Echoes, B. Mills

<u>Hyperwall</u>

Tuesday & Thursday, 9:10AM-9:35AM NASA's Decadal Mission Concept Studies: HabEx, LUVOIR, Lynx, OST, D. Pooley & A. Vikhlinin (Lynx)

Wednesday, 9:10AM-9:20AM Revealing the Dawn of Black Holes with the Lynx X-ray Observatory, R. Hickox

Friday, 9:20AM-9:30AM Revealing the Invisible Drivers of Galaxy and Structure Formation and Evolution, J. Kollmeier

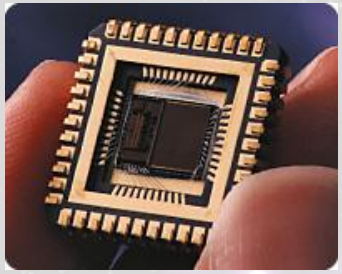
Science Driven Instrument Requirements

X-RAY OBSERVATORY LYNX

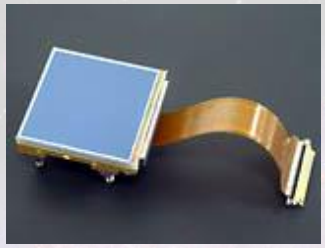
High-Definition X-ray Imager

Optimized for deep survey science

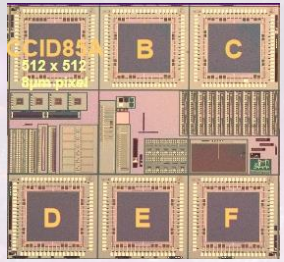
- Silicon sensors with ~ 0.3″ pixels
- FOV ≥ 20'×20'
- Δ *E* ~ 100 eV over 0.1–10 keV band
- High frame rates to minimize pile-up.



Monolithic CMOS



Hybrid CMOS



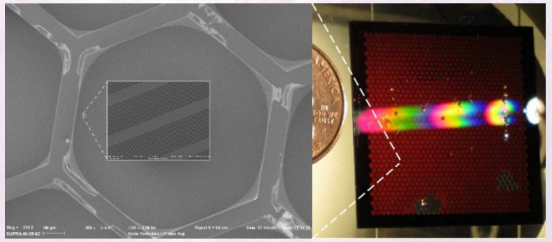
Digital CCD with CMOS readout

X-ray Grating Spectrometer

Detail outflow velocities and mass loss rates to provide information on matter and energy feedback in accreting galaxies.

Map the unobserved, large fraction of baryons that likely exists in the hot phase of the intergalactic medium.

Off-Plane Grating Array



Critical Angle Transmission – Grating Array

- Resolving power $\lambda/\Delta\lambda > 5000$
- Effective area > 4000 cm^2 covering X-ray emission and absorption lines of C, O, Mg, Ne, and Fe-L.

Key Instrument Requirements

X-RAY OBSERVATORY LYNX

Lynx X-ray Microcalorimeter

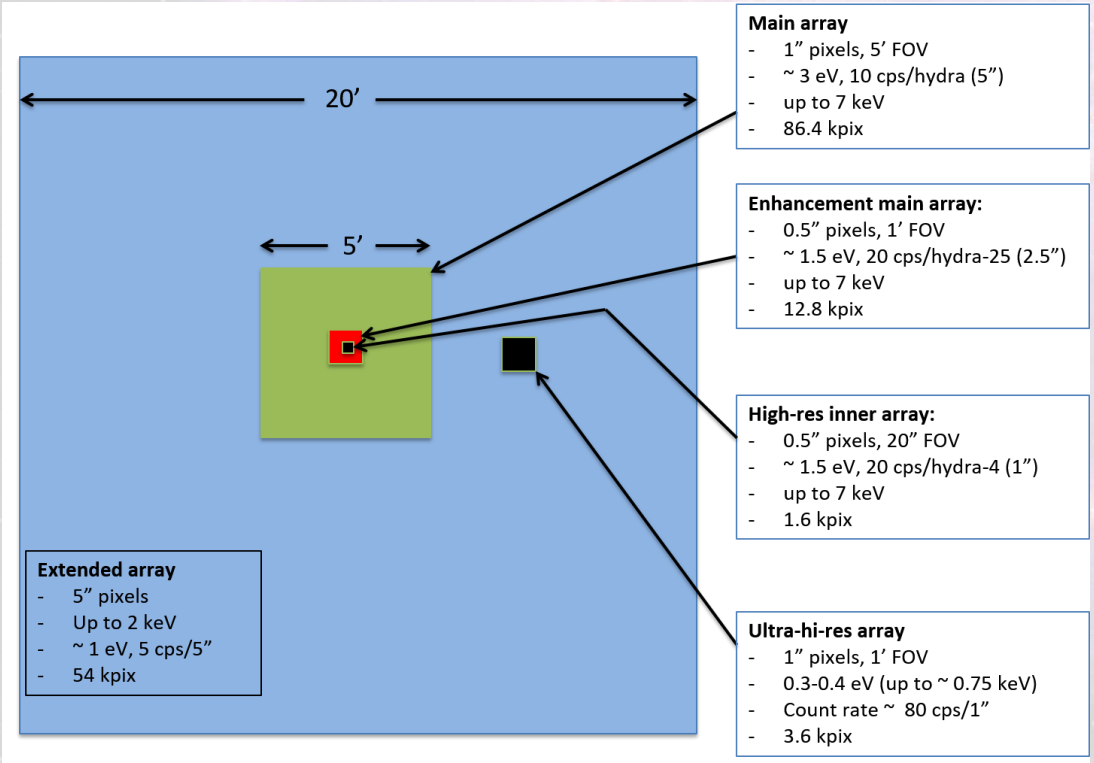
- *Main Array* provides non-dispersive spectroscopy with Δ *E* < 3 eV over the 0.2–7 keV band and imaging with 1″ pixels over a 5'×5' FOV
- Several subarrays are optimized for sub-arcsec imaging, 0.3 eV energy resolution, and coverage of 20'×20' FOV.

*Enhancement Main Array: O*ptimized to allow for higher count-rates, such as from AGN

*High-Res Inner Array: O*ptimized to allow for higher count-rates, such as from AGN

Ultra-High-Res Array: Enables the study of turbulent line broadening around individual galaxies through the study of the highly ionized oxygen lines

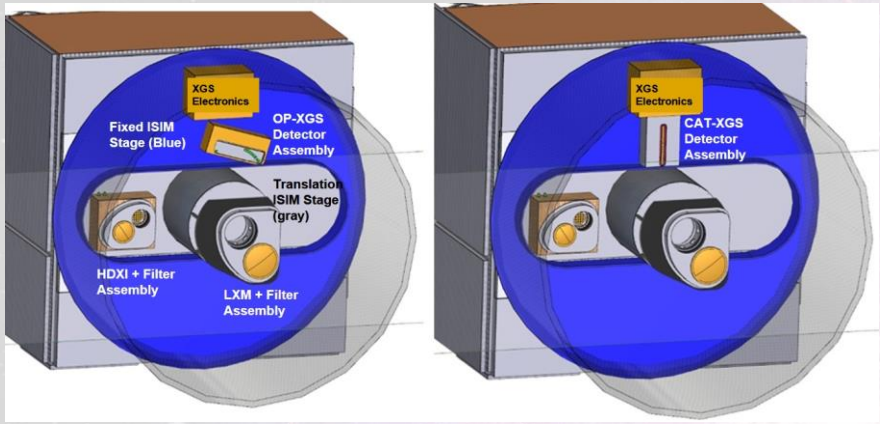
Extended Array: Surveys over large regions of the sky for observations of the soft diffuse emission from extended galaxies, the outer regions of galaxy groups and clusters and also cosmic filaments



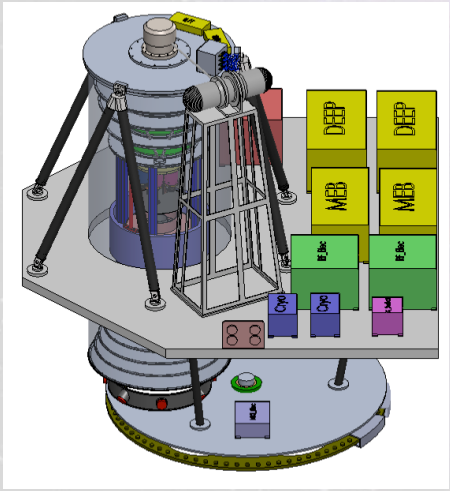
Instrument Design Studies

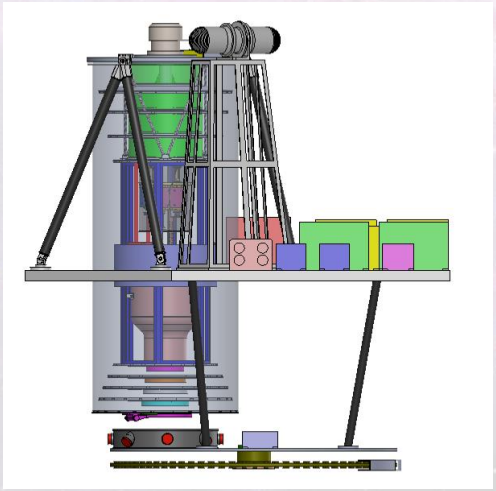
MSFC Advanced Concept Office performed a comprehensive Design Study for HDXI and XGS (for both Off-Plane and Critical Angle Transmission Grating readouts)

- *Configuration*
- *Structures*
- *Mechanisms*
- *Thermal*
- *Power*
- *Electronics*
- *Cost*



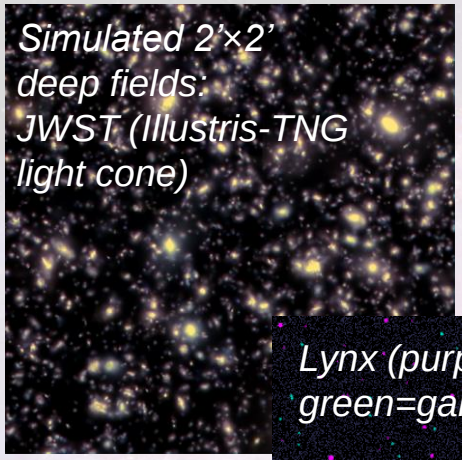
GSFC contributed an Instrument Design Lab for LXM, including baseline and updated cost modeling

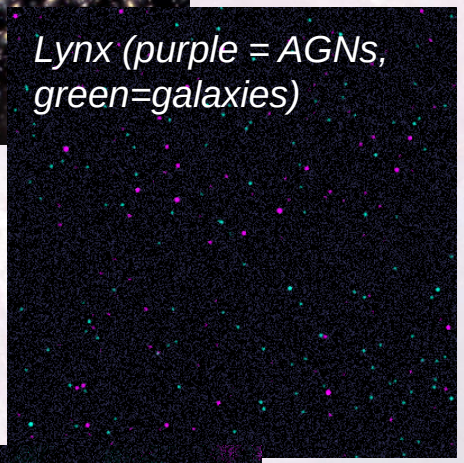


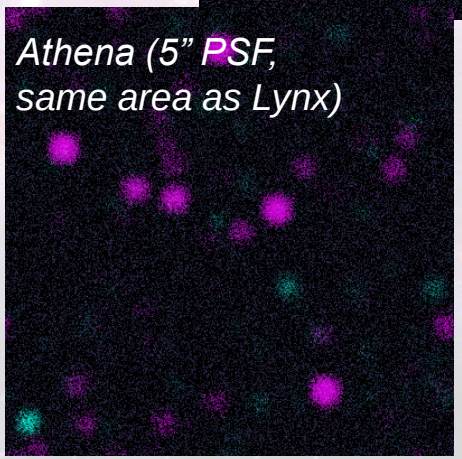


Optical Assembly Requirements

Angular resolution (on-axis)	0.5 arcsec HPD (or better)
Effective area @ 1 keV	~2 m^2 (met with 3-m OD)
Grasp, A*(FOV for HPD < 1 arcsec)	~600 m^2 $arcmin^2$
Wide FOV sub-arcsec Imaging	10 arcmin radius







Science Traceability:

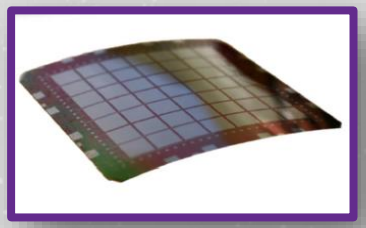
Lynx will find the first supermassive black holes in the first galaxies detected by JWST, trace their growth from the seed phase, and shed light on how they subsequently co-evolve with the host galaxies. Needed sensitivities, 10^{-19} erg/s/cm^2, are ~ 200× below *ATHENA* confusion limit.

- Angular resolution < 1″ (50% power diameter) will avoid source confusion and limit background
- An Effective area > 2m^2 and FOV > 10' in radius with arcsecond or better imaging will survey sufficient volume at z=10 in less than 25 Msec.

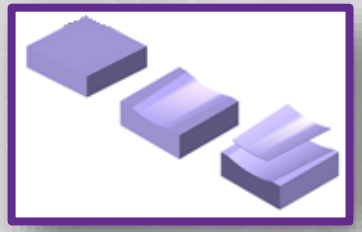
Lynx Optics Technology Study

Lynx will use the Kepner-Tregoe trade process to select an optics technology for the Lynx Design Reference Mission and to establish feasibility for alternate viable technologies. – *Supported by G. Blackwood, NASA Exoplanet Exploration Program*

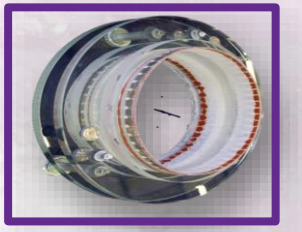
Study has been initiated for 3 Viable Optics Technologies



Adjustable Optics
(Study Lead: P. Reid/SAO)



Si Meta-Shell Optics
(Study Lead: W. Zhang/GSFC)



Full Shell Optics
(Study Leads: K. Kilaru/USRA/MSFC, G. Pareschi/INAF/OAB)

Selection will be based on Science, Technical and Programmatic criteria (TBD)

The Lynx Optics Working Group will make a formal recommendation to STDT in Summer 2018!

Lynx Optics Technology Study

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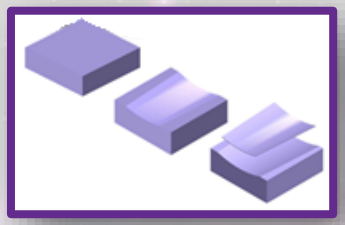
FABRICATION

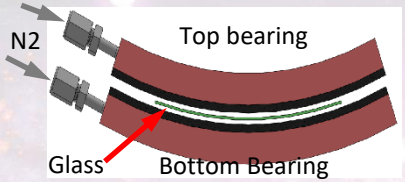
Thermal Forming (GSFC, SAO)

Full Shell (Brera, MSFC, SAO)

Si Optics (GSFC)

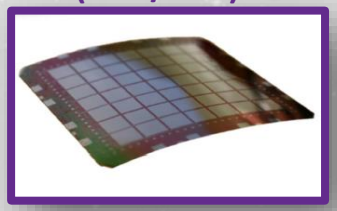


Air Bearing Slumping (MIT)

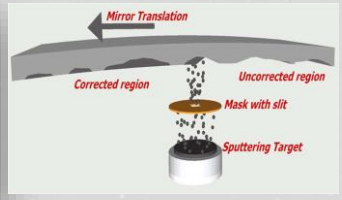


CORRECTION

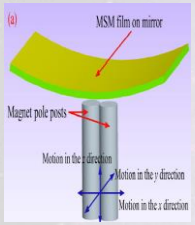
Piezo stress (SAO/PSU)

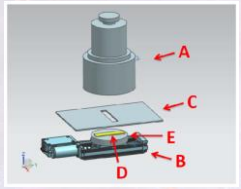


Deposition (MSFC, XRO)

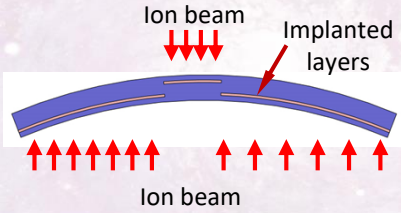


Magnetic & deposition stress (NU)

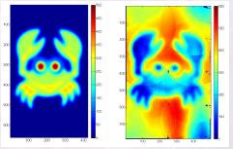




Ion implant stress (MIT)

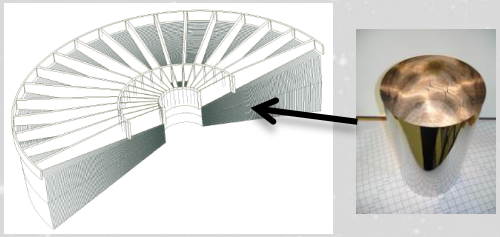


Ion beam figuring (OAB)

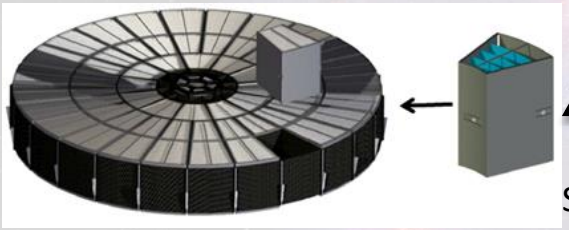


INTEGRATION

Full shells Assembly

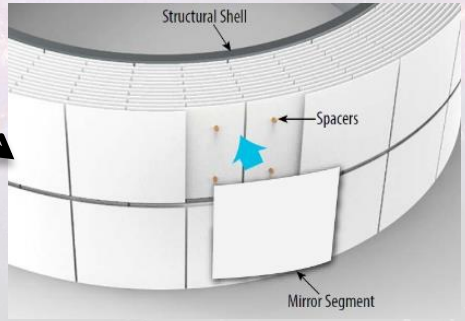


Segmented Wedge Assembly



Segments

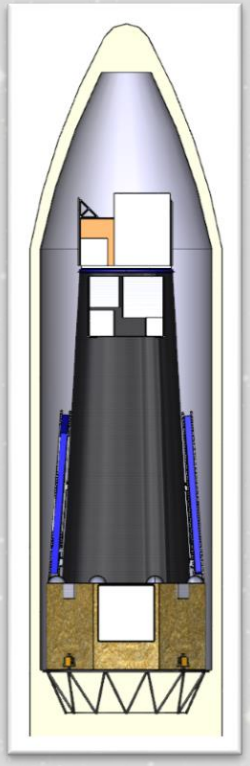
Meta-Shell Assembly



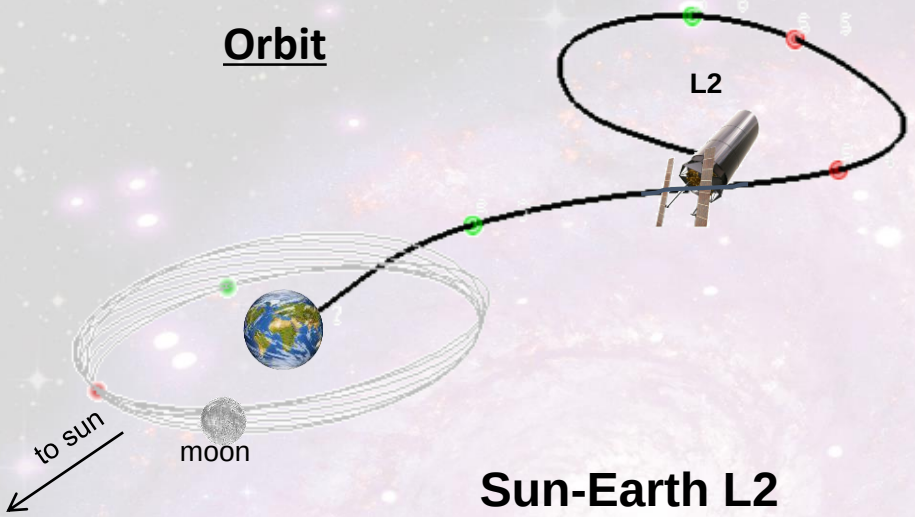
Mission Design Study

Launch Vehicle

Most likely will need a Heavy-class launch vehicle (TBC)



Orbit



Mission Lifetime : Baseline mission is 5 years, extendable for an additional 20 years based on consumables (still need to complete analysis on L2 radiation environment)

Mission Operations: Chandra-like. Lynx will have a primary science program combined with a general observer program

Lynx Observatory

X-RAY OBSERVATORY
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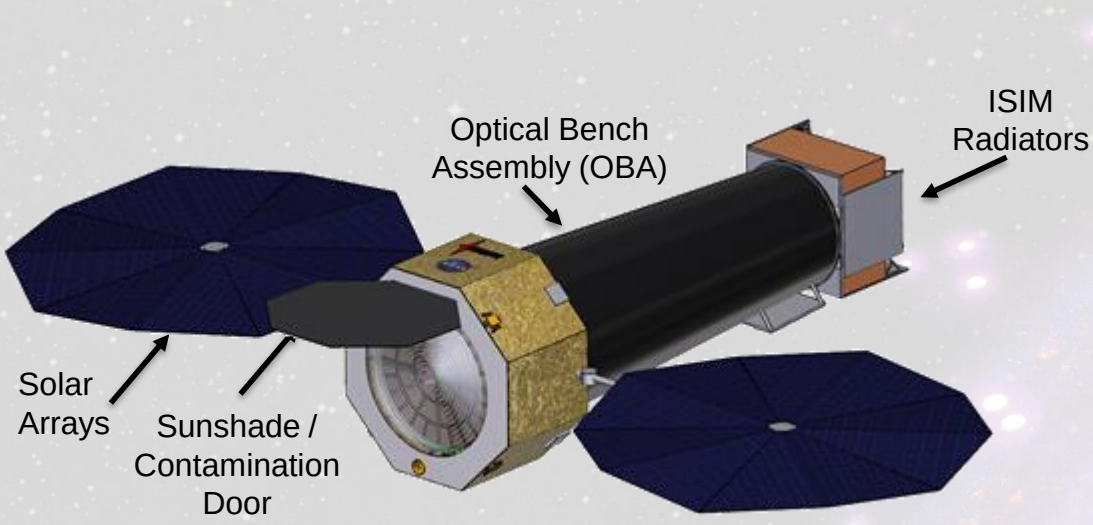
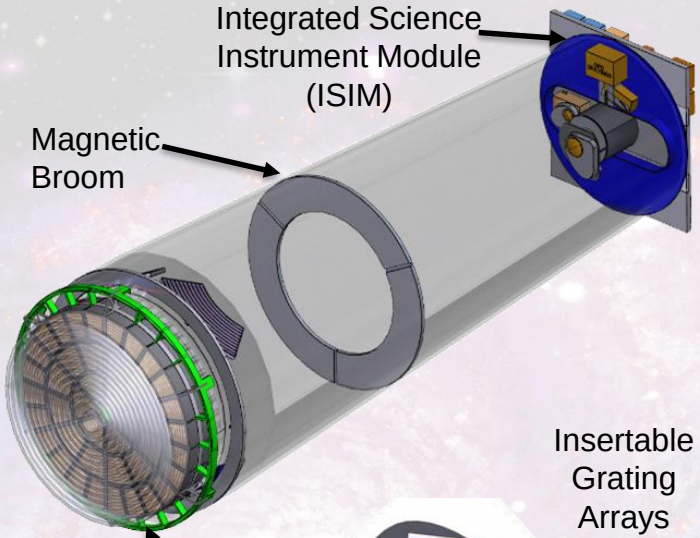
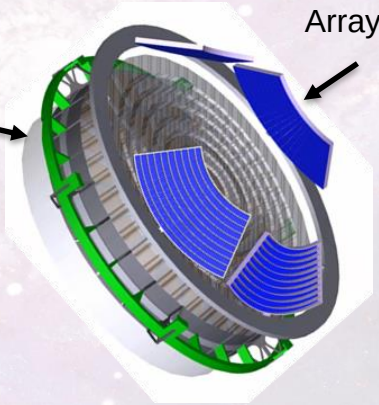
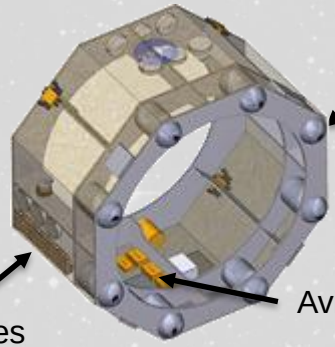




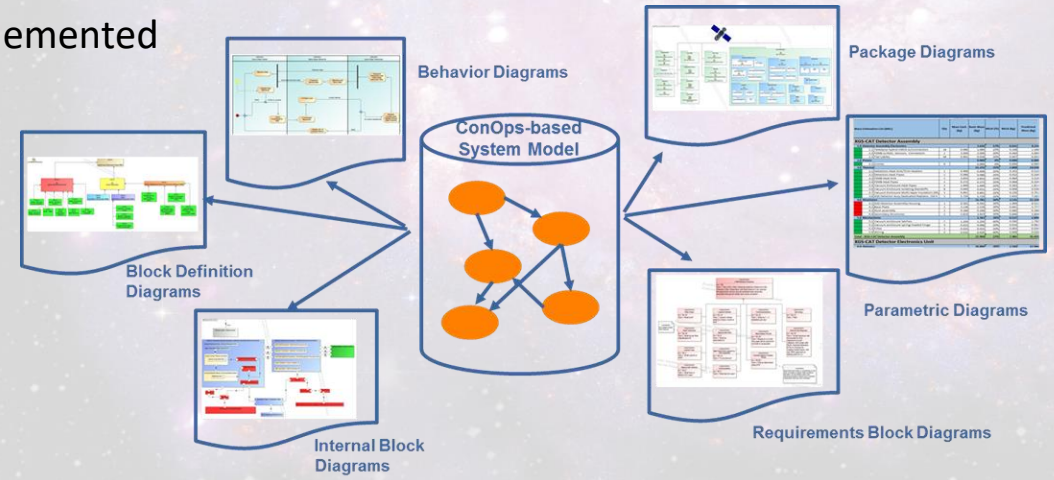




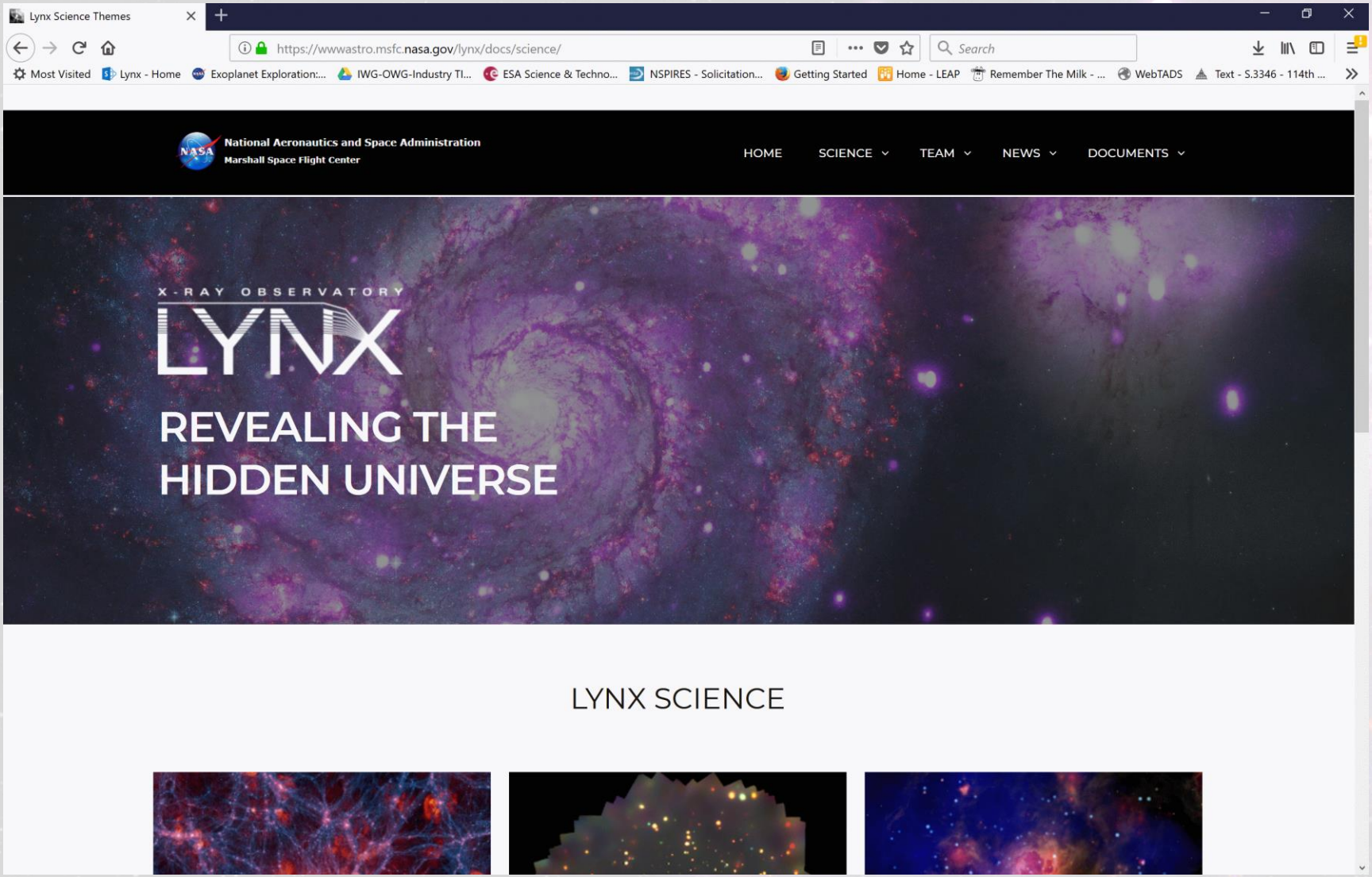
Under Refinement!

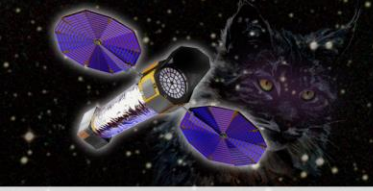
2017 Additional Accomplishments

- Awarded 5 Cooperative Agreement Notices (CANs) to industry partners to support payload design and programmatics
- Science Traceability Matrix was developed
- Interim Report first draft completed and reviewed by Red Team
- Major improvements to the Lynx simulation package (http://hea-www.cfa.harvard.edu/~jzuhone/soxs/)
  - Astrophysical backgrounds now include resolved point sources
  - A module to generate an X-ray light cone from a cosmological situation was added
  - Instrument specifications were added for imaging observations of ACIS-I and ACIS-S, Cycles 0 and 19, Hitomi/SXS, and AXIS.
  - The ability to generate gratings spectra for Lynx and Chandra ACIS-S/HETG was added.
- Model Based Systems Engineering implemented



Updated Website



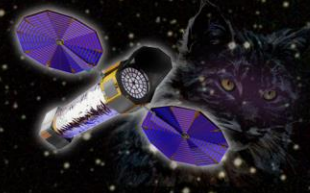


2018 Key Tasks

X-RAY OBSERVATORY LYNX

- Submit Interim Report to HQ (due 03/2018)
- Continue to strengthen science case and traceability to observatory architecture
- Improve fidelity of instruments, observatory, and mission concept design (MSFC and GSFC)
- Complete Optics Technology Study
- Complete Technology Roadmap for Optics and Instruments
- Complete Risk Assessment and Independent Costing for Lynx
- Carry out Informal CATE with Aerospace
- Initiate Final Report

Next STDT F2F is 01/25/18-01/26/18 in Houston, TX



X-RAY OBSERVATORY

LYNX

REVEALING THE INVISIBLE UNIVERSE

Thank you!

- ***Please visit the Lynx Display next to the Chandra Table and the Decadal Studies Table for more information***
- ***Participation is open and welcome at any level. For more information and to sign-up to our News Distribution, visit our website at: https://wwwastro.msfc.nasa.gov/lynx/***